

On the Distribution of Radium in the Earth's Crust

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On the Distribution of Radium in the Earth's Crust.

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Part II.—SEDIMENTARY ROCKS.

In a paper read before the Society on April 5, I gave determinations of the quantity of radium in igneous rocks. Similar data for sedimentary deposits will now be given to complete my survey of the radium content of the earth's crust.

The limestones examined (oolite, chalk, marble, etc.) were simply dissolved in hydrochloric acid, and the emanation extracted from the solution. All other rocks (including sandstones, clays, slates, gravel) were first fused with sodium carbonate, in exactly the same way as the igneous rocks dealt with in the former paper. I believe that in some cases, clays for instance, this is unnecessary; for determinations made on clay simply treated with hydrochloric acid gave the full quantity of emanation.* But to avoid any doubt, fusion was always resorted to.

The results for sedimentary rocks are given in Table I.

Table I.

Rock.	Locality.	Radium per gramme, in grammes.
Oolite	Bath	5.84×10^{-12}
Oolite	St. Alban's Head	4.05×10^{-12}
Marble	East Lothian	3.87×10^{-12}
Kimmeridge clay	Ely	3.77×10^{-12}
Oil-bearing sandstone ...	Gallicia	3.04×10^{-12}
Roofing slate	Wales (?)	2.57×10^{-12}
Silicified gritty slate	St. Ives, Cornwall	2.50×10^{-12}
Gault clay	Cambridge	2.13×10^{-12}
Clay	Terling, Essex	1.73×10^{-12}
Red sandstone	East Lothian	1.68×10^{-12}
Gravel (fine siftings)	Terling, Essex	1.42×10^{-12}
Red chalk	Hunstanton	1.07×10^{-12}
Flint (large nodules) ...	Terling, Essex	1.06×10^{-12}
White marble	Deccan, India	0.54×10^{-12}
Marble	East Lothian	0.52×10^{-12}
Chalk	Bottom of pit, Cherry Hinton, Cambridgeshire ...	0.78×10^{-12}
Chalk†	Top of same pit	0.25×10^{-12}

* The emanation cannot be quantitatively extracted from clay by merely boiling it with water.

† This determination was made on 500 grammes of material, in order to get a sufficient leak for measurement.

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On comparing these figures with those given in my former paper for igneous rocks,* it will be observed that the average radium content of sedimentary deposits does not differ appreciably from that of igneous rocks. This is what might be expected on the received view that sedimentary rocks derive their material from the disintegration of igneous ones.

It appears then that the examination of sedimentary rocks for radium gives no reason for altering the estimate of the radium content of the earth's crust formerly arrived at.

I have examined a few other materials which cannot be properly described as rocks, but which are of interest in the present connection.

The results are given below:—

Table II.

Material.	Radium per gramme in grammes.
Deposit from hot springs, Bath	828×10^{-12}
Cambridge tap-water†	0.78×10^{-12}
Sea-salt (approximate determination only)...	0.15×10^{-12}
Boiler crust, Cambridge.....	0.078×10^{-12}

It will be noticed that the deposit from the Bath spring is 100 times as rich as any rock. The materials transported by cold water, sea salt, and boiler crust are, on the other hand, much poorer in radium than any of the rocks.

Part III.—ROCK-FORMING MINERALS.

Igneous rocks are aggregates of many distinct minerals. It was felt that the enquiry as to the distribution of radium in such rocks would be incomplete without some attempt to determine in which of these minerals that element chiefly resides.

Most of the rock-forming minerals can be obtained in large well developed crystals. Such crystals occur for the most part in exceptional localities where crystallisation has been extremely slow, and where the structure of the rocks is on a large scale throughout. In these cases it is easy to obtain any desired quantity of the pure mineral for investigation.

I have examined a number of such specimens of rock-forming minerals for radium. The results are given in Table III. In some cases the quantity of material taken for the experiment proved insufficient to give a satisfactory quantitative measure of the amount of radium in the mineral. This is

* 'Roy. Soc. Proc.,' vol. 77, A, p. 479, last column but one of the table.

† This is the quantity of radium which corresponds to the emanation dissolved in 1 c.c. of the water. The radium is not itself present in the water.

indicated by a note of interrogation. In other cases no radium at all was detected. In all probability some traces would have been found if more of the mineral had been taken, but the object was to determine whether the mineral made any important contribution to the total radium in the rock. Thus it was not thought worth while to push the examination of accessory minerals, such as ilmenite or rutile, which only occur in small proportions, very far. The quantities of material taken for these experiments are given, so that the quantitative significance of a negative result may be judged.

Table III.

Mineral.	Locality where found.	Quantity taken, grammes.	Radium per gramme, in grammes.
Zircon	Ural Mountains	1	865×10^{-12}
Zircon	North Carolina	1	658×10^{-12}
Zircon	Brevig	0·690	139×10^{-12}
Zircon	Kimberley	1·17	$74·8 \times 10^{-12}$
Perovskite	Magnet Cove, Arkansas	1	197×10^{-12}
Sphene	?	1	102×10^{-12}
Apatite	Sweden	8	$29·7 \times 10^{-12}$
Apatite	California	4·7	$11·0 \times 10^{-12}$
Hornblende	?	7·5	$4·27 \times 10^{-12}$
Tourmaline	Devonshire	11·3	$3·32 \times 10^{-12}$
Labradorite	Labrador	17	$1·1 \times 10^{-12} ?$
White felspar	Nellore, India	20	$0·6 \times 10^{-12} ?$
White mica	Nellore, India	10	$1·0 \times 10^{-12} ?$
Brown mica	Deccan	10	$1·0 \times 10^{-12} ?$
Brown mica	?	10	Nil.
White quartz	Nellore, India	30	Nil.
Rutile	?	1	Nil.
Ilmenite	?	1	Nil.

It will be observed that certain of the accessory minerals, *i.e.*, zircon, sphene, perovskite and apatite, which occur in granite, are rich in radium. The hornblende, micas, tourmaline and feldspars examined contain much less, while in quartz none could be detected.

Although these experiments throw a certain amount of light on the subject, they are in some respects inconclusive. It is not safe to take these exceptional cases where large crystals occur, as typical; for slow crystallisation is likely to result in more perfect separation of the constituent elements. Moreover, it is difficult to form any idea of the proportion in which the various minerals occur, especially when there has been no opportunity of examining them *in situ*. One cannot tell, for instance, whether enough zircon occurs to account for any large fraction of the radium contained in the whole rock. I have accordingly made some experiments by separating the constituents of an ordinary rock. For this purpose Cornish granite was

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selected, as being comparatively rich in radium, and coarse enough to allow of easy separation of the constituent minerals. Sixty-five grammes of Cornish granite was powdered just so far that each particle was seen to be composed of one mineral only, when examined with a magnifier. Bromoform was used to separate the dense minerals from the light ones. The dense minerals, which sank, weighed only 7·5 grammes. The rest of the powder, consisting of quartz and felspar, floated on the liquid.

The dense portion consisted mainly of brown mica, but may have contained some zircon enclosed between the flakes, the separation of which by mechanical methods would be impracticable. The dense portion was accordingly digested with hydrochloric acid until the flakes had lost all their colour, nothing but silica remaining. This treatment would leave the zircon behind, as it is not appreciably acted on by hydrochloric acid.

The rock was thus divided into three portions. The quantity of radium in each of these portions was determined by the usual method.

The result was that 1 gramme of Cornish granite contains :—

	Radium.
In the light portion (quartz and felspar).....	$3\cdot85 \times 10^{-12}$ gramme.
In the heavy portion, soluble in HCl (brown mica) ...	$4\cdot27 \times 10^{-12}$ „
In the heavy portion, insoluble in HCl (zircon ?)	$1\cdot02 \times 10^{-12}$ „
Total	$9\cdot14 \times 10^{-12}$ „

It appears therefore that more than half of the radium is contained in the heavy minerals, though these are only 1/8 of the whole mass of the rock. Although the separation by means of bromoform was not perfect, it was, I think, good enough to make it certain that a considerable portion of radium is really contained in the light constituents. As to the heavy minerals, it would not seem that there is enough zircon to account for much of the radium, which chiefly resides in the brown mica.

It appears that radium, or rather its parent, uranium, is not perfectly separated from a rock magma by the crystallisation of the heavy constituents, though considerable concentration in these constituents occurs.